Tanta University

Faculty of Engineering

MECHANICAL DESIGN of OVERHEAD TRANSMISSION LINES (OHTL)

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General Considerations

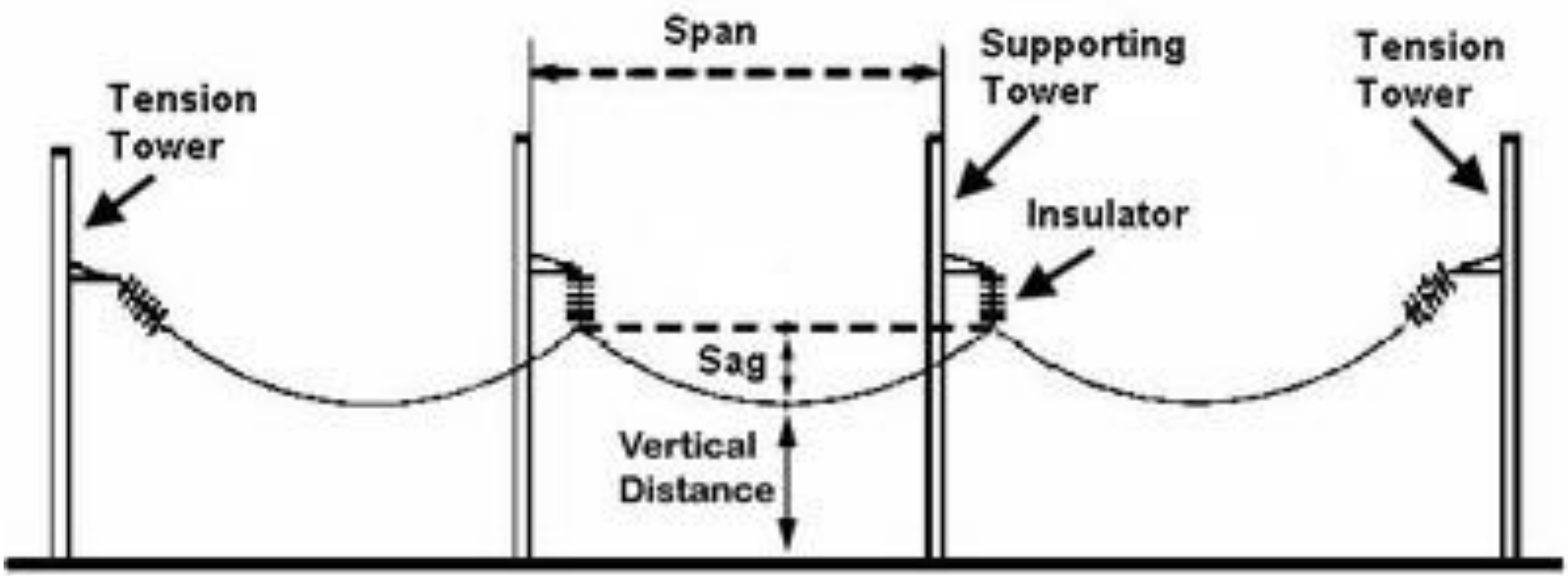
Electrical Considerations for T.L. Design:

- **Low voltage drop**
- **Minimum power loss for high efficiency of power transmission.**
- **The line should have sufficient current carrying capacity so that the power can be transmitted without excessive voltage drop or overheating.**

Mechanical Considerations for T.L. Design:

- **The conductors and line supports should have sufficient mechanical strength:**

- **to withstand conductor weight, Conductor Tension and weather conditions (wind, ice).**
- **The Spans between the towers can be long.**
- **Sag will be small.**
- **Reducing the number and height of towers and the number of insulators.**


Span
Tension
Tower
Supporting
Tower
Tension
Tower
Insulator
Sag
Vertical
Distance

Main components of Overhead lines:

(i) Conductors
(ii) Supports
(iii) Insulators
(iv) Cross arms
(v) Other items such as lightning arrestors.

Line Supports Properties:

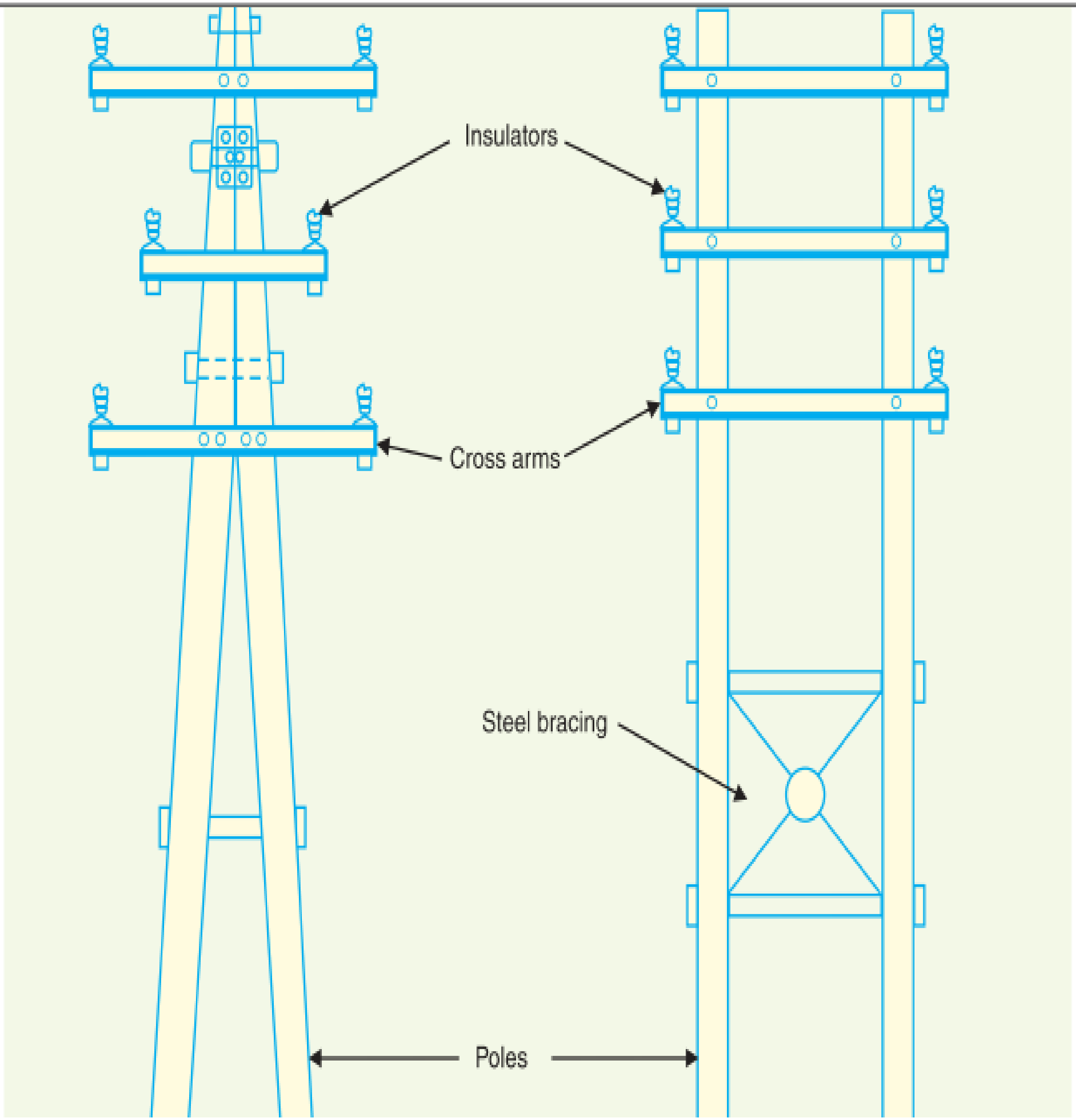
- High mechanical strength to withstand weight of conductor
- Light in weight
- Cheap in cost
- Longer life
- Easy accessibility of conductor for maintenance

Types of Line Supports:-

- Wooden poles
- Steel poles
- Reinforced Concrete Poles (RCC)
- Lattice steel towers

Wooden poles

- Shorter span up to 50 m
- Less cost & used for distribution purpose in rural areas
- Pesticides required e.g creosote oil
- Used for voltage up to 20 kv
- Smaller life(20-25 years)
- Less mechanical strength
- Made of Sal or Chir
- Moderate cross-sectional area


Insulators
Cross arms
Steel bracing
Poles

Wooden Poles

Steel Poles

- Greater mechanical strength
- Longer life
- Larger spans
- Used for distribution purpose in cities
- Three types:
  - Rail poles
  - Tubular poles
  - Rolled steel joints

Steel Poles

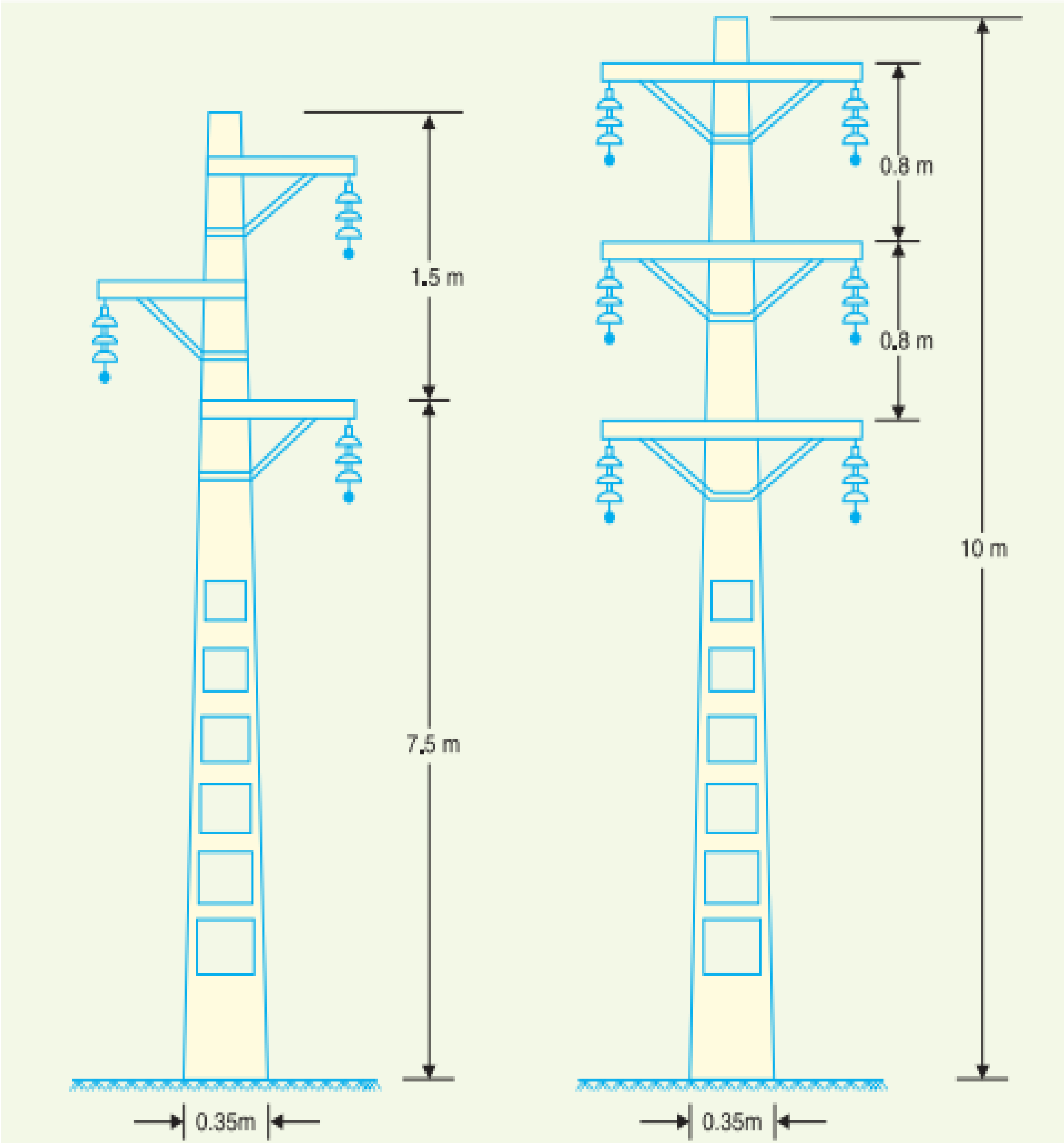
RCC(Reinforced concrete poles):-

- Greater mechanical strength
- Longer life
- Longer spans
- Good outlook
- Little maintenance
- Good insulating properties

Two Types:-

Single pole

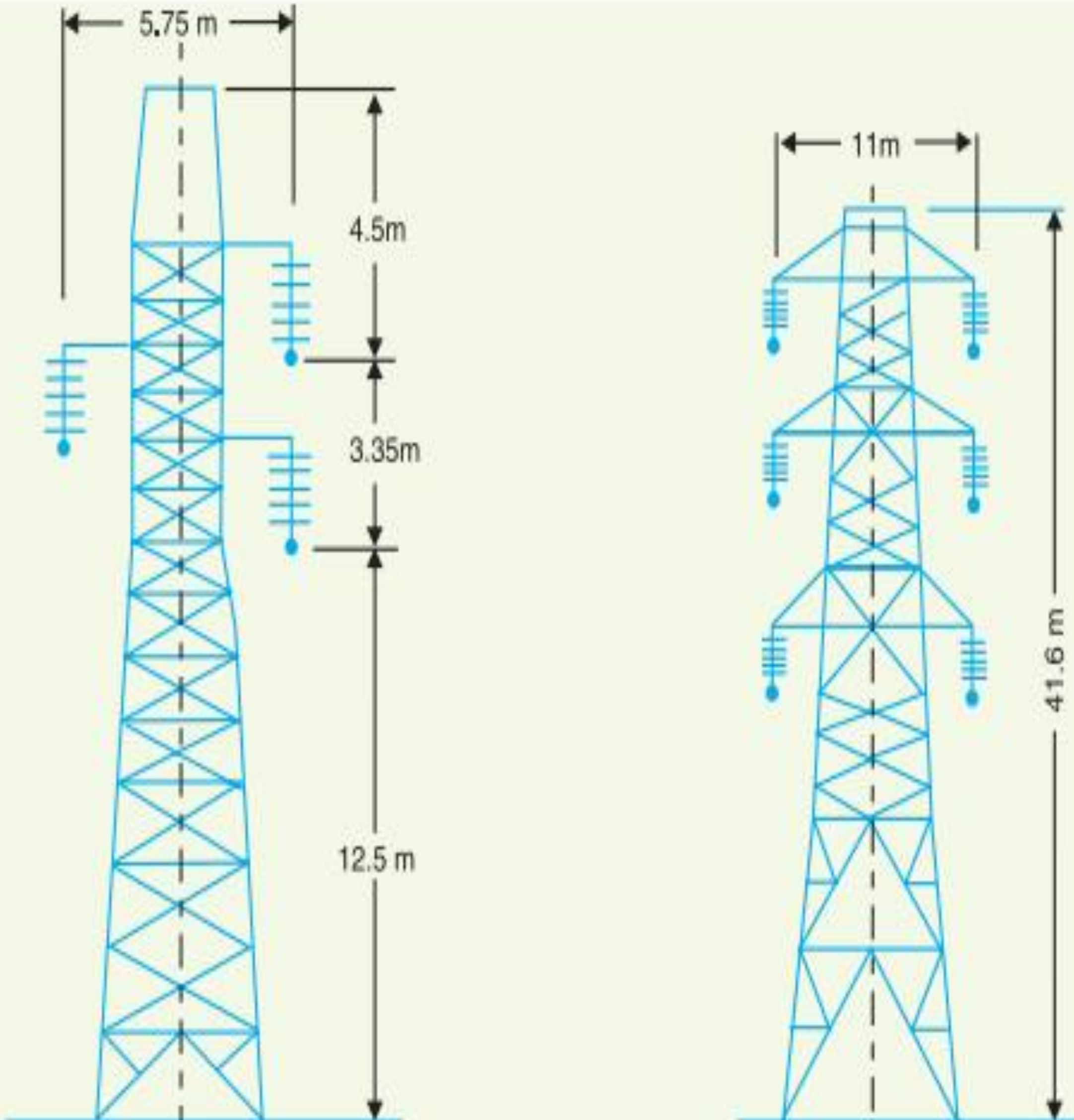
Double poles


1.5 m
7.5 m
0.35m
0.8 m
0.8 m
10 m
0.35m

Reinforced Concrete Poles

Steel towers :-

- Longer life
- Longer span
- Greater mechanical strength
- For long distance at high voltage
- Tower footings are usually grounded by driving rods into the earth .This minimizes lightning troubles as each tower acts as lightning conductor.



110 kV, Span 320 m

(i)

220 kV, Span 320 m

(ii)

Types of Towers

1- Suspension Tower

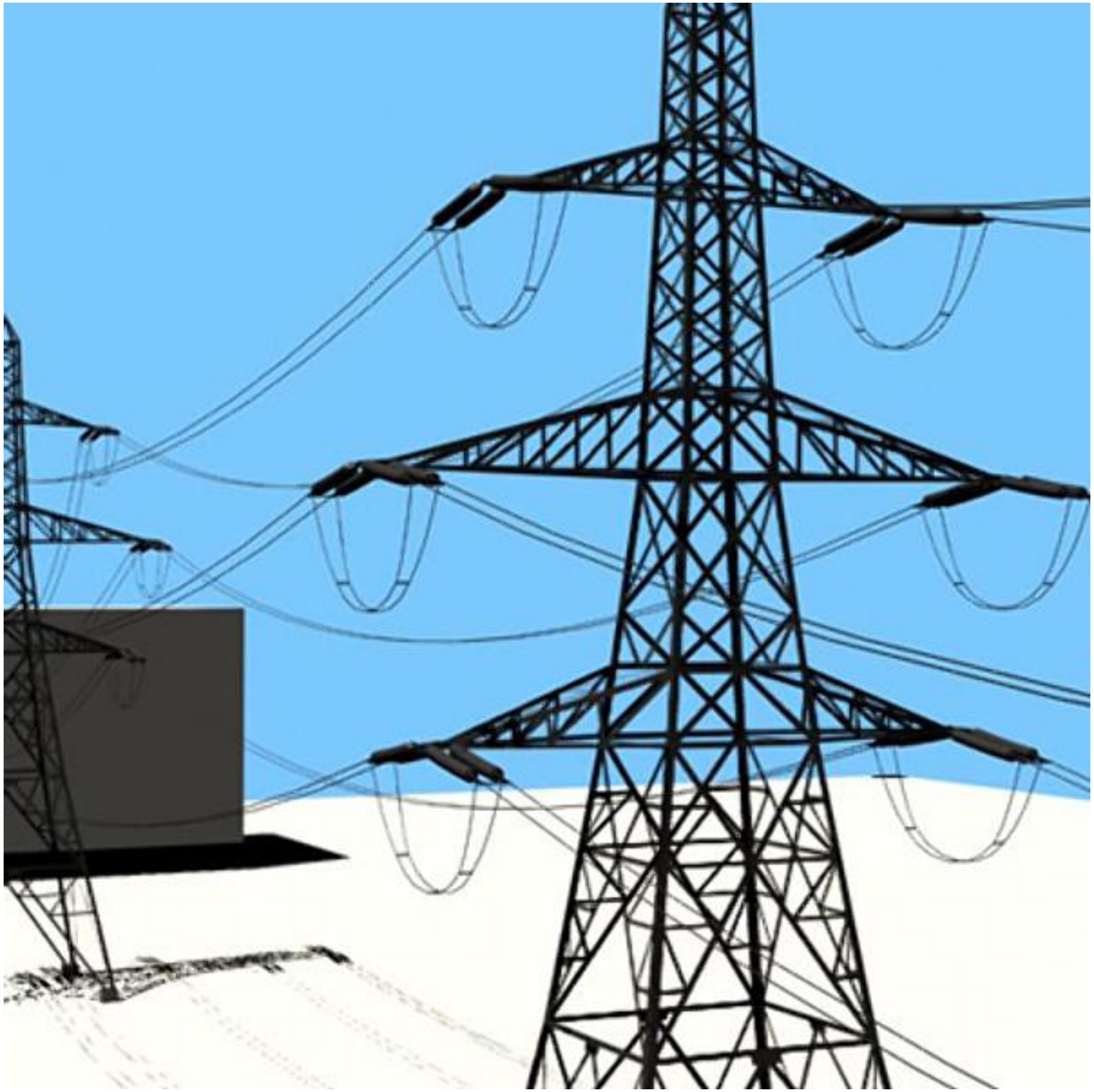
2- Tension Tower

3- Angle Tower

4- End Tower

1- Suspension Tower

2- Tension Tower



3- Angle Tower

4- End Tower

This type of towers exists in the beginning and at the end of the line which exposed to tension in one side.

Insulators in overhead transmission lines

Insulators in overhead transmission lines

Properties of Insulating Material

The materials generally used for insulating purpose is called **insulating material**. For successful utilization, this material should have some specific properties as:-

- It must be mechanically strong enough to carry tension and weight of conductors.
- It must have very high dielectric strength to withstand the voltage stresses in High Voltage system. (high relative permittivity).
- It must possesses high Insulation Resistance to prevent leakage current to the earth.

Insulators in overhead transmission lines

Properties of Insulating Material

The materials generally used for insulating purpose is called **insulating material**. For successful utilization, this material should have some specific properties as:-

- The **insulating material** must be free from unwanted impurities.
- It should not be porous.
- There must not be any entrance on the surface of electrical insulator so that the moisture or gases can enter in it.

Insulators in overhead transmission lines

Properties of Insulating Material

The materials generally used for insulating purpose is called **insulating material**. For successful utilization, this material should have some specific properties as:-

- There physical as well as electrical properties must be less effected by changing temperature.

Types of Insulator

There are mainly three types of insulator likewise:

1. Pin Insulator
2. Suspension Insulator
3. Strain Insulator

In addition to that there are other two types of electrical insulator available mainly for low voltage application, e.i. stay insulator and shackle insulator.

Types of Insulator

1.Pin Insulator

Pin Insulator is earliest developed **overhead insulator**, but still popularly used in power network up to 33 KV system.

Pin type insulator can be one part, two parts or three parts type, depending upon application voltage.

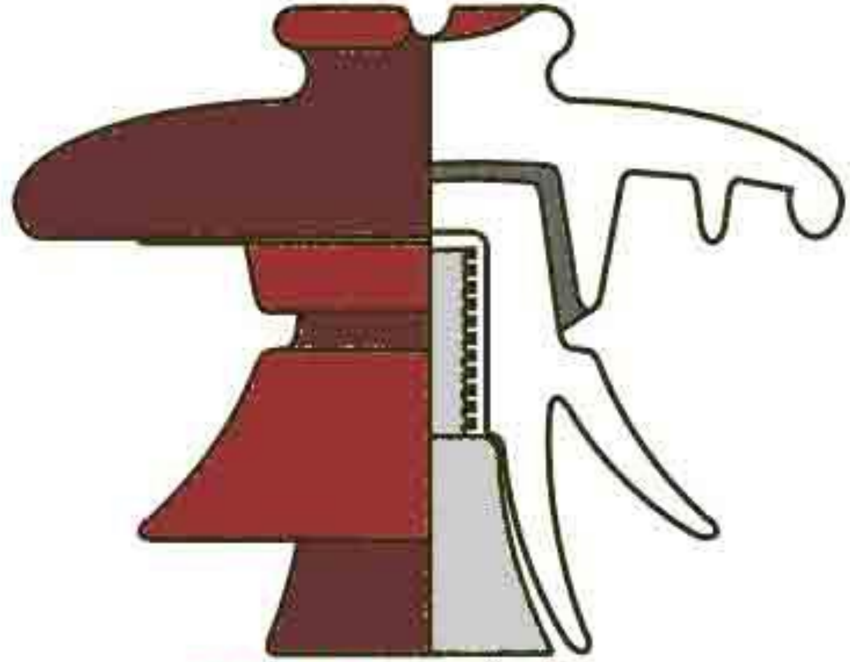
In 11 KV system we generally use one part type insulator where whole pin insulator is one piece of properly shaped porcelain or glass.

Types of Insulator

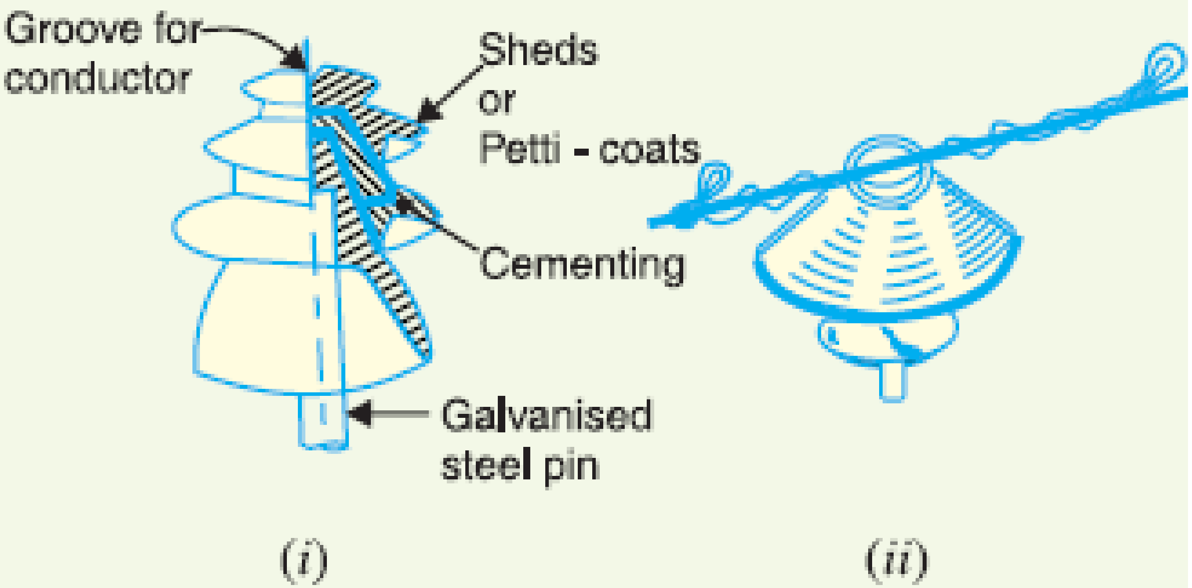
1.Pin Insulator

As the leakage path of insulator is through its surface, it is desirable to increase the vertical length of the insulator surface area for lengthening leakage path.

Pin type insulator



33KV Pin Insulator



Types of Insulator

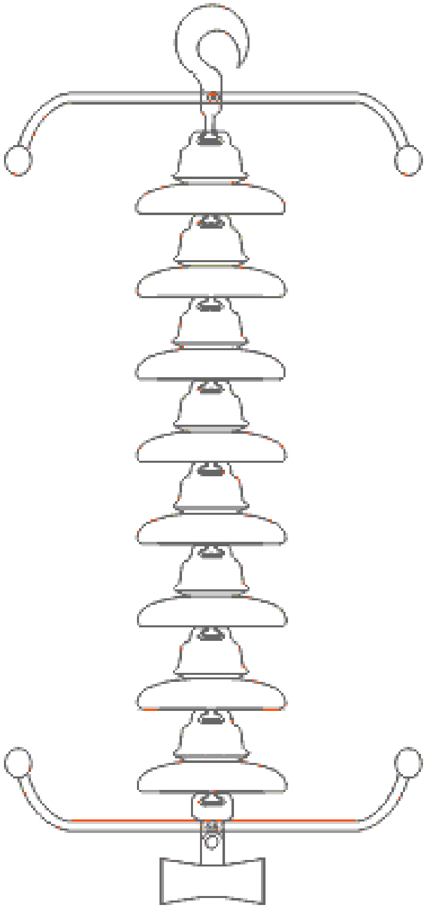
2. Suspension Insulator

In higher voltage, beyond 33KV, it becomes uneconomical to use pin insulator because size, weight of the insulator become more. Handling and replacing bigger size single unit insulator are quite difficult task. For overcoming these difficulties, suspension insulator was developed.

In **suspension insulator** numbers of insulators are connected in series to form a string and the line conductor is carried by the bottom most insulator. Each insulator of a suspension string is called disc insulator because of their disc like shape.

Types of Insulator

2. Suspension Insulator



Suspension String

Suspension insulator

Types of Insulator

2. Suspension Insulator

Advantages of Suspension Insulator

1.Each suspension disc is designed for normal voltage rating 11KV (Higher voltage rating 15KV), so by using different numbers of discs, a suspension string can be made suitable for any voltage level.

2.If any one of the disc insulators in a suspension string is damaged, it can be replaced much easily.

3.Mechanical stresses on the suspension insulator is less since the line hanged on a flexible suspension string.

4.As the current carrying conductors are suspended from supporting structure by suspension string, the height of the conductor position is always less than the total height of the supporting structure. Therefore, the conductors may be safe from lightening.

Types of Insulator

2. Suspension Insulator

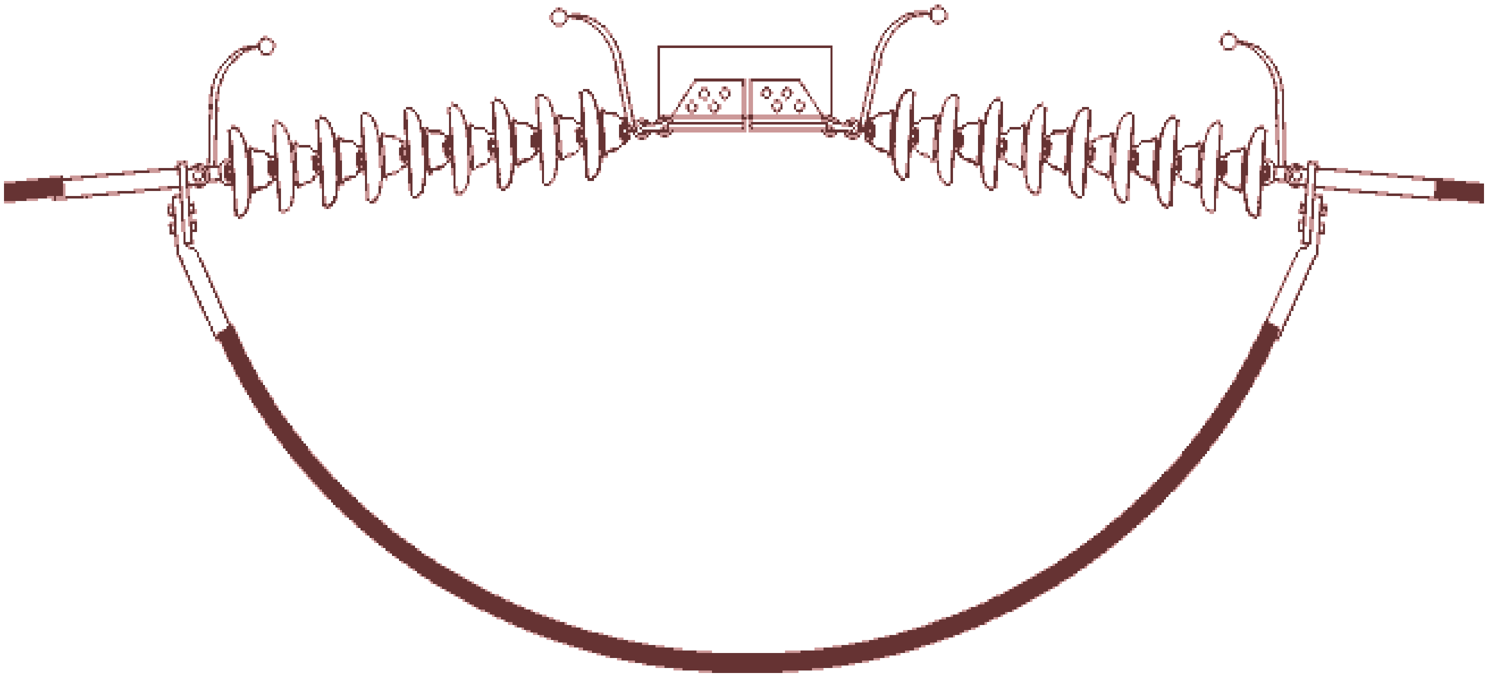
Disadvantages of Suspension Insulator

1. Suspension insulator string costlier than pin and post type insulator.
2. Suspension string requires more height of supporting structure than that for pin or post insulator to maintain same ground clearance of current conductor.
3. The amplitude of free swing of conductors is larger in suspension insulator system, hence, more spacing between conductors should be provided.

Types of Insulator

3. Strain Insulator

When suspension string is used to sustain extraordinary tensile load of conductor it is referred as **string insulator**. When there is a dead end or there is a sharp corner in transmission line, the line has to sustain a great tensile load of conductor or strain. A **strain insulator** must have considerable mechanical strength as well as the necessary electrical insulating properties

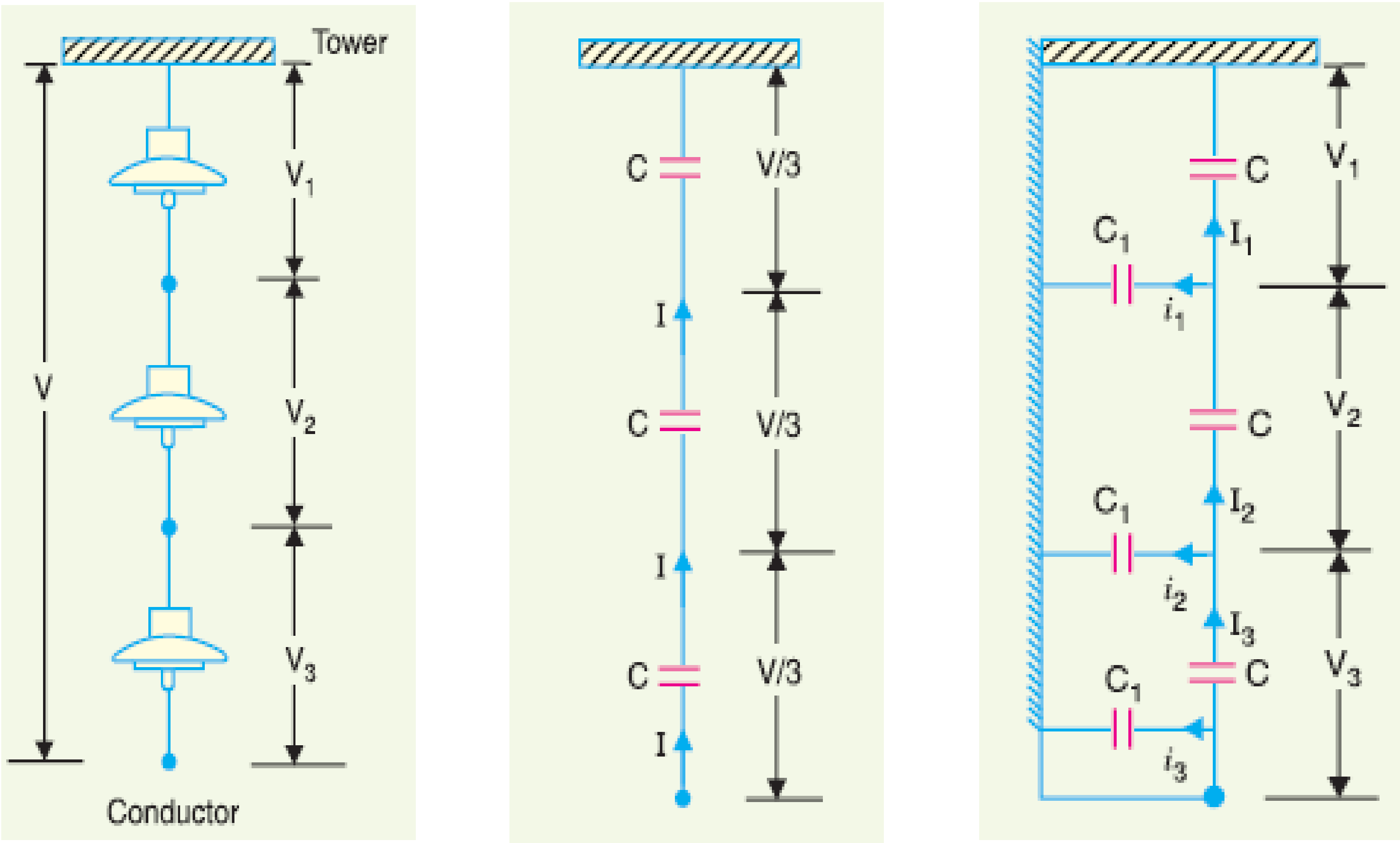


STRAIN INSULATOR

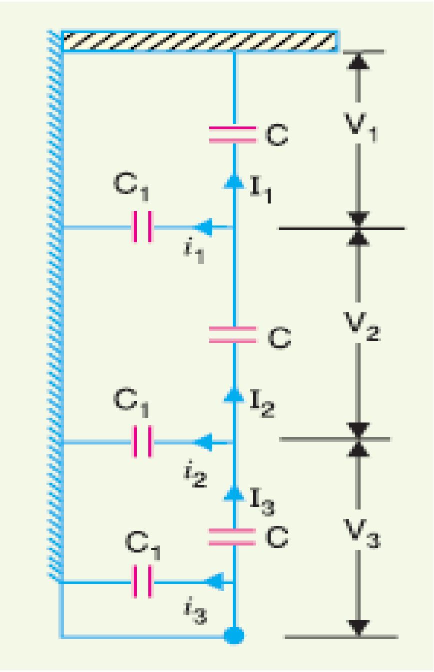
Number of disc insulator used in string

Rated System Voltage	Number of disc insulator used in strain type tension insulator string	Number of disc insulator used in suspension insulator string
33KV	3	3
66KV	5	4
132KV	9	8
220KV	15	14

Potential distribution over suspension insulator string



Potential distribution over suspension insulator string



The following points may be noted regarding the potential distribution over a string of suspension insulators :

(i) The voltage impressed on a string of suspension insulators does not distribute itself uniformly across the individual discs due to the presence of shunt capacitance.

(ii) The disc nearest to the conductor has maximum voltage across it. As we move towards the cross-arm, the voltage across each disc goes on decreasing.

(iii) The unit nearest to the conductor is under maximum electrical stress and is likely to be punctured. Therefore, means must be provided to equalise the potential across each unit. This is fully discussed in Art. 8.8.

(iv) If the voltage impressed across the string were d.c., then voltage across each unit would be the same. It is because insulator capacitances are ineffective for d.c.

String Efficiency

The ratio of voltage across the whole string to the product of number of discs and the voltage across the disc nearest to the conductor is known as **string efficiency** *i.e.,*

$$\text{String efficiency} = \frac{\text{Voltage across the string}}{n \times \text{Voltage across disc nearest to conductor}}$$

where n = number of discs in the string.

Applying Kirchhoff's current law to node A, we get,

$$I_2 = I_1 + i_1$$

or $$V_2 \omega C^* = V_1 \omega C + V_1 \omega C_1$$

or $$V_2 \omega C = V_1 \omega C + V_1 \omega K C$$

$\therefore$ $$V_2 = V_1 (1 + K) \qquad ...(i)$$

Applying Kirchhoff's current law to node B, we get,

$$I_3 = I_2 + i_2$$

or $$V_3 \omega C = V_2 \omega C + (V_1 + V_2)\, \omega C_1 \dagger$$

or $$V_3 \omega C = V_2 \omega C + (V_1 + V_2)\, \omega K C$$

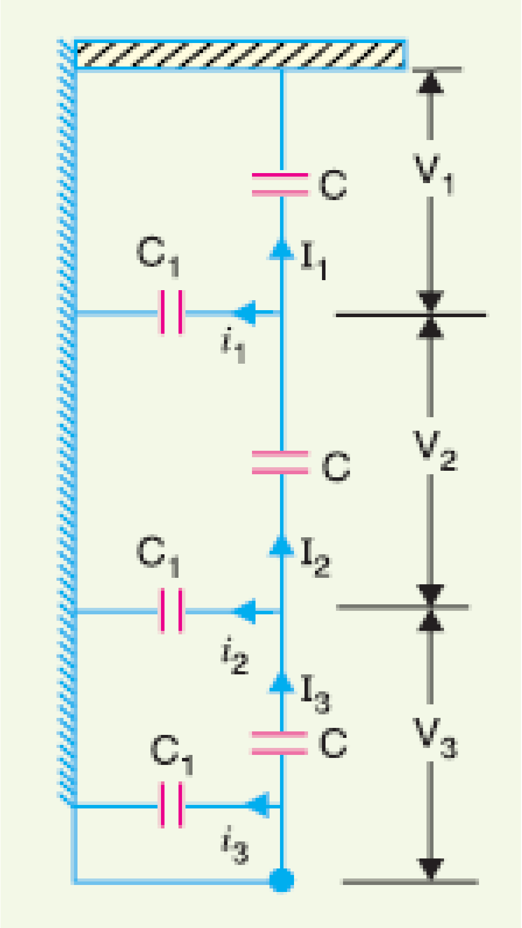
or $$V_3 = V_2 + (V_1 + V_2) K$$

$$= K V_1 + V_2 (1 + K)$$

$$= K V_1 + V_1 (1 + K)^2$$

$$= V_1 [K + (1 + K)^2]$$

$\therefore$ $$V_3 = V_1 [1 + 3K + K^2]$$



String Efficiency

Voltage between conductor and earth (*i.e.*, tower) is

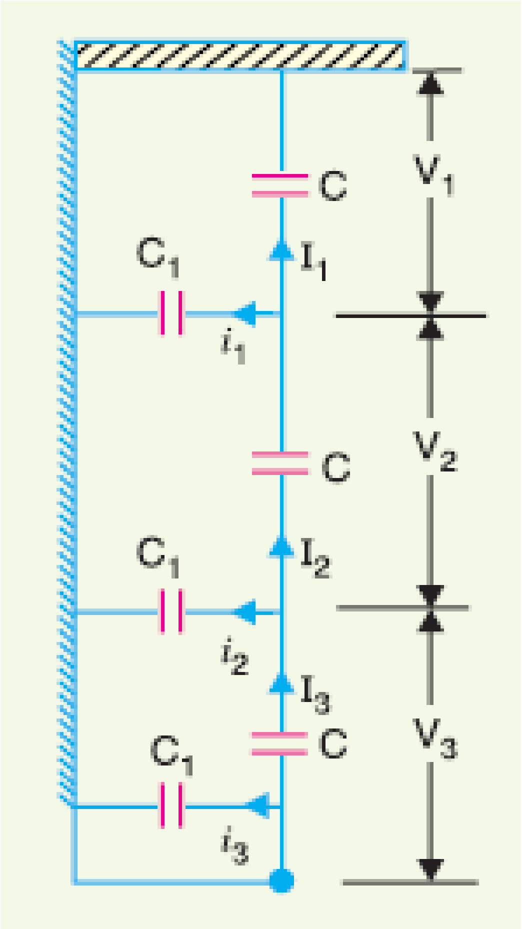
$$V = V_1 + V_2 + V_3$$
$$= V_1 + V_1(1+K) + V_1(1+3K+K^2)$$
$$= V_1(3+4K+K^2)$$

$$\therefore \quad V = V_1(1+K)(3+K)$$

From expressions (*i*), (*ii*) and (*iii*), we get,

$$\frac{V_1}{1} = \frac{V_2}{1+K} = \frac{V_3}{1+3K+K^2} = \frac{V}{(1+K)(3+K)}$$

$$\therefore \text{Voltage across top unit, } V_1 = \frac{V}{(1+K)(3+K)}$$



$$\text{Voltage across second unit from top, } V_2 = V_1(1+K)$$
$$\text{Voltage across third unit from top, } V_3 = V_1(1+3K+K^2)$$

$$\text{\%age String efficiency} = \frac{\text{Voltage across string}}{n \times \text{Voltage across disc nearest to conductor}} \times 100$$
$$= \frac{V}{3 \times V_3} \times 100$$

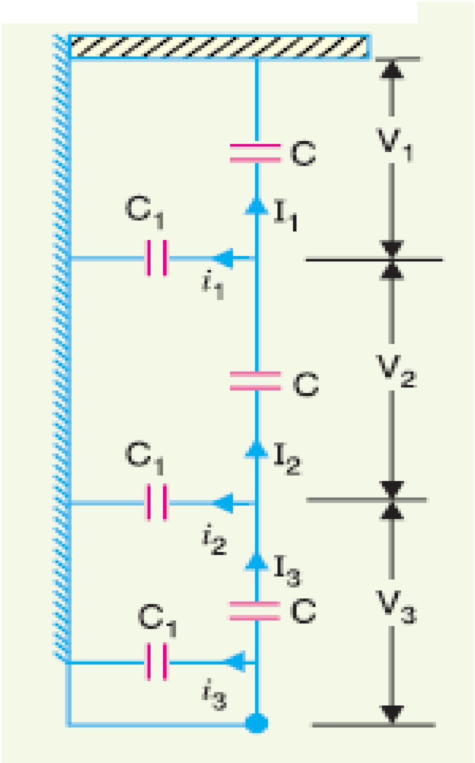
String Efficiency

The following points may be noted from the above mathematical analysis :

(*i*) If $K = 0{\cdot}2$ (Say), then from exp. (*iv*), we get, $V_2 = 1{\cdot}2\ V_1$ and $V_3 = 1{\cdot}64\ V_1$. This clearly shows that disc nearest to the conductor has maximum voltage across it; the voltage across other discs decreasing progressively as the cross-arm in approached.

(*ii*) The greater the value of $K\ (= C_1/C)$, the more non-uniform is the potential across the discs and lesser is the string efficiency.

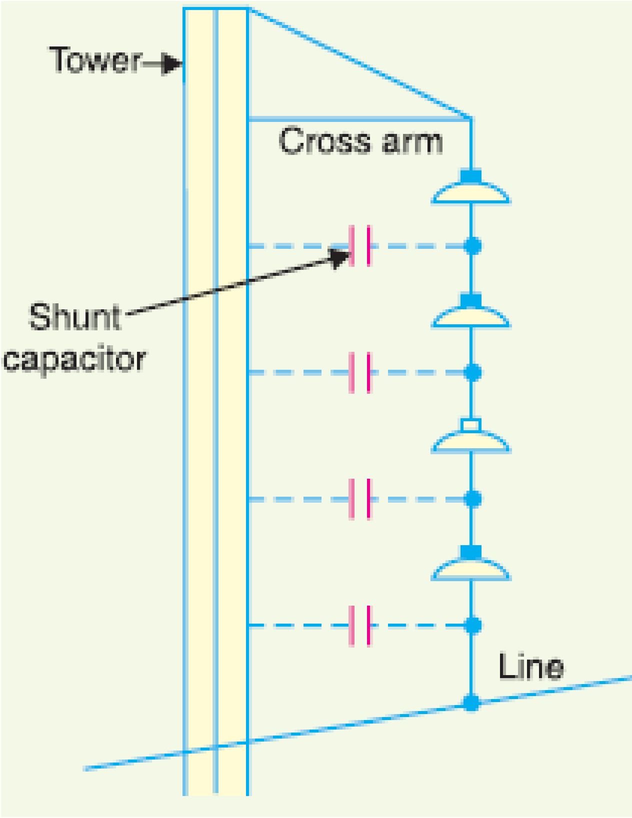
(*iii*) The inequality in voltage distribution increases with the increase of number of discs in the string. Therefore, shorter string has more efficiency than the larger one.



Methods of Improving String Efficiency

1.By using longer cross-arms. The value of string efficiency depends upon the value of K i.e., ratio of shunt capacitance to mutual capacitance. The lesser the value of K, the greater is the string efficiency and more uniform is the voltage distribution.

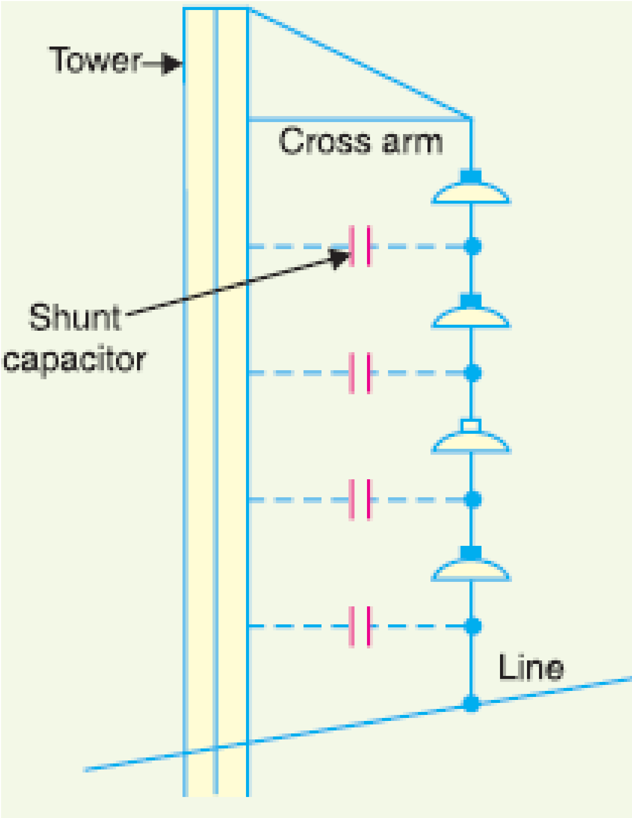
The value of K can be decreased by reducing the shunt capacitance. In order to reduce shunt capacitance, the distance of conductor from tower must be increased i.e., longer cross-arms should be used. However, limitations of cost and strength of tower do not allow the use of very long cross-arms. In practice, K = 0·1 is the limit that can be achieved by this method.



Methods of Improving String Efficiency

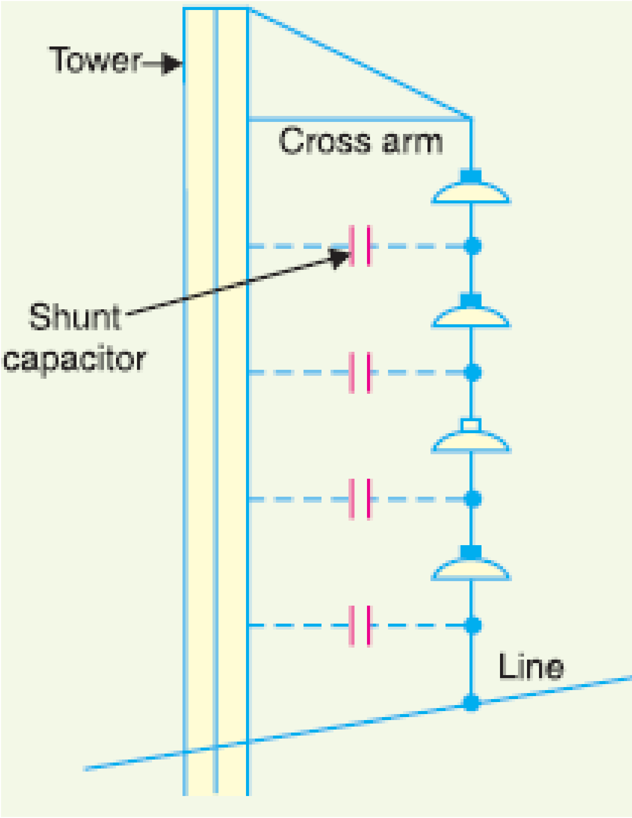
2.By grading the insulators. In this method, insulators of different dimensions are so chosen that each has a different capacitance. The insulators are capacitance graded i.e. they are assembled in the string in such a way that the top unit has the minimum capacitance, increasing progressively as the bottom unit (i.e., nearest to conductor) is reached.

Since voltage is inversely proportional to capacitance, this method tends to equalize the potential distribution across the units in the string. This method has the disadvantage that a large number of different-sized insulators are required. However, good results can be obtained by using standard insulators for most of the string and larger units for that near to the line conductor.



Methods of Improving String Efficiency

1.By using a guard ring. The potential across each unit in a string can be equalised by using a guard ring which is a metal ring electrically connected to the conductor and surrounding the bottom insulator. The guard ring introduces capacitance between metal fittings and the line conductor. The guard ring is contoured in such a way that shunt capacitance currents i1, i2 etc. are equal to metal fitting line capacitance currents i′1, i′2 etc. The result is that same charging current I flows through each unit of string. Consequently, there will be uniform potential distribution across the units.



Methods of Improving String Efficiency